Reprinted from “Bulletin of Marine Science” Volume 44, 1989, pp. 200-219, Thayer and Chester: Distribution and abundance of fishes among basin and channel habitats in Florida Bay. With permission from Rosenstiel School of Marine and Atmospheric Science of the University of Miami.

BULLETIN OF MARINE SCIENCE, 44(1): 200–219, 1989

DISTRIBUTION AND ABUNDANCE OF FISHES AMONG BASIN AND CHANNEL HABITATS IN FLORIDA BAY

Gordon W. Thayer and Alexander J. Chester

ABSTRACT

Surface and bottom trawls were used to sample fishes in basins and channels in the western half of Florida Bay. These data were evaluated in conjunction with information on environmental parameters, including seagrasses, to identify fish-habitat associations. Florida Bay is utilized by a diverse fish assemblage dominated by juveniles and forage species. The western portion of our sampling area within Florida Bay, adjacent to the Gulf of Mexico, and channels within the Bay consistently supported the highest diversity of fish. Channel areas generally displayed the highest overall standing crop and density of seagrasses. Basins in the western portion of the Bay were most diverse in terms of seagrass composition and exhibited the highest overall densities of *Syringodium filiforme.* Cluster analysis revealed two major station groups. One, characterized by fish species that occurred frequently and in large numbers, occurred primarily in channels and in western Florida Bay where mixtures of seagrasses were prevalent; a second, characterized by low fish densities, occurred in generally monotypic stands of *Thalassia testudinum.* Discriminant function analysis demonstrated that comparatively higher sediment organic contents, slightly shallower water, and abundant *Halodule wrightii* and *Syringodium* populations were important factors at stations belonging to the typically high density fish cluster.

The wetland and estuarine areas of Florida are critical to the valuable commercial and recreational fisheries of the state and Nation because 70–90% of the harvested species in the Gulf of Mexico depend on coastal wetlands and submerged seagrass meadows of bays and estuaries for at least part of their life cycle (Lindall and Saloman, 1977). These coastal ecosystems provide pre-recruits with abundant food resources, a relative scarcity of predators, and, in low salinity areas, less competition with adults. Upland and wetland areas of coastal Florida, however, have undergone extensive modification over the past century due to the development of residential and industrial complexes, water diversion canals, and highways. There is growing concern that these alterations are adversely impacting marine fishery resources (Colby et al., 1985; Everglades National Park, pers. comm.). During the 1970's fishing guides and recreational fishermen, concerned about declining catches, began to demand a reallocation of resources between commercial and recreational fishing. Since that time, and because of these concerns, the Park has gradually phased out commercial fishing (Davis, 1982).

There are relatively few publications addressing the ecological relationships in estuarine habitats of Everglades National Park, specifically those affecting juvenile fishes and other fishes with small adult sizes. Tabb and Manning (1961; 1962) and Tabb and Dubrow (1962) provide lists of invertebrate and fish species in portions of the area and include information on temperature-salinity distributions and general habitats of these species. These data predate the perceived decline in harvest (Davis, 1982) and pertain primarily to Whitewater Bay, Coot Bay and western Florida Bay. Odum et al. (1982), Schomer and Drew (1982), and Zieman (1982) summarized general distributions of fishery organisms associated with mangrove-lined environments and seagrass meadows, but little quantitative information has been available prior to 1985 on juvenile and forage fishes and their associated habitats (Powell et al., 1986; Sogard et al., 1987; Thayer et al., 1987a; 1987b; papers in this Symposium).

The basin, bank and channel habitats of Florida Bay are dominated by seagrasses, and, although *Syringodium filiforme* and *Halodule wrightii* occur in the Bay, *Thalassia testudinum* predominates (Zieman and Fourqurean, 1985; Zieman et al., 1989). These investigators have demonstrated considerable geographic variation in plant diversity, shoot density, and canopy height within the Bay, and have delimited seven vegetational zones based on seagrass and algal distribution. The diversity of plant species as well as location of habitats may be influential in regulating both faunal species abundance and the complement of species present. Coupled with this diversity of plant habitat types are geologic zones (Schomer and Drew, 1982) which also may influence faunal distribution patterns.

The objectives of our study were two-fold: (1) to evaluate the distribution and relative abundance of juvenile fish and forage fish in the western and central portion of Florida Bay and (2) to attempt to evaluate the influence of environmental parameters on this distribution.

Materials and Methods

Sampling Location.—Florida Bay is a lagoonal estuary lying between the Florida mainland and the Florida Keys. It comprises a network of carbonate mud banks that separate the bay into shallow basins, generally dominated by seagrasses. Our sampling area included basins and channels in western and central Florida Bay (Fig. 1a). The basin area was subdivided into three approximately equal-sized strata (Fig. 1a) based on the general distribution of benthic vegetation (Zieman and Fourqurean, 1985) and discussions with Mr. J. Fourqurean (Univ. Va., pers. comm.). Although variable plant biomasses were evident, Zieman and Fourqurean (1985) reported the lowest *Thalassia* standing crop for Stratum I, generally intermediate standing crops for Stratum II, and highest values for Stratum III. A fourth group of stations (Stratum IV), located in channels between carbonate mud banks and between islands, was selected from Nautical Chart-11451 and after on site inspection (Fig. 1b).

Potential sampling locations within the basin strata were determined using a grid system. Each grid cell represented a square area approximately 1,800 m on a side, and there were 93, 98 and 107 potential sampling cells in Strata I, II and III, respectively (Thayer et al., 1987b). Six cells were randomly selected for each basin strata for each sampling period. Three alternate cells also were selected for each stratum in case any of the six selected stations turned out, during the actual survey, to be unsampleable (i.e., if we were unable to reach the area due to shallow depths). Six channels were sampled on each date, with the channels being selected by a random procedure. We established a depth range of 0.5–2.3 m within which we would sample, and if the basin area fell outside the range, an alternate cell was used; this depth range did not pertain to channels. Prior to sampling we eliminated 8, 12 and 23 sample grids in Strata I, II, and III, respectively (Thayer et al., 1987b), because they were either too shallow (<0.5 m) or too deep (>2.3 m).

Sampling Approach.—Biological, physical and chemical data were collected from the approximate mid-point of a randomly-chosen grid cell. Surveys were carried out in May, June, July, September and November 1984 and January, March, May and June 1985.

Two types of trawls were used; an otter trawl was deployed for benthic fishes and crustaceans and a surface trawl for natant fishes. The otter trawl was made from tarred nylon netting, 6-mm bar with a 3-mm mesh tail bag. The net measured 3.4 m at the head rope and 3.8 m at the foot rope and was fitted with 3-mm galvanized tickler chain strung between the otter doors. The surface trawl was a modification of the net described by Massman et al. (1952). It measured 6.6 m at the head rope, 6.2 m at the foot rope and was 0.7 m deep. Wing mesh was 6-mm bar with a 3-mm mesh tail bag. Both were pulled at a speed of 2.0 ± 0.2 m/s (3.5–4.5 k) between two 5-m-long boats with 25-hp outboard engines.

Each trawl was pulled for 2 min in a downwind direction (except when confined to narrow channels). A floating marker was put overboard at the beginning and another at the end of each tow, distance measured with an optical range finder, and the area covered calculated knowing the distance and mouth opening of the net. After each trawl, fish were separated from plant material, placed in labelled sample bags, and preserved in 10% formalin. Fish and crustaceans were identified to species, counted, blotted and weighed.

Surface and bottom temperature and salinity were measured (YSI model 33 S-C-T meter) at each station, midway along and adjacent to each trawl line. At salinities in excess of 37‰ a refractometer (surface water only) was employed. A diver took triplicate 100 cm^2 samples of vegetation plus a sample of surface sediment at each station (Thayer et al., 1987b). On each occasion a marked pole was pushed

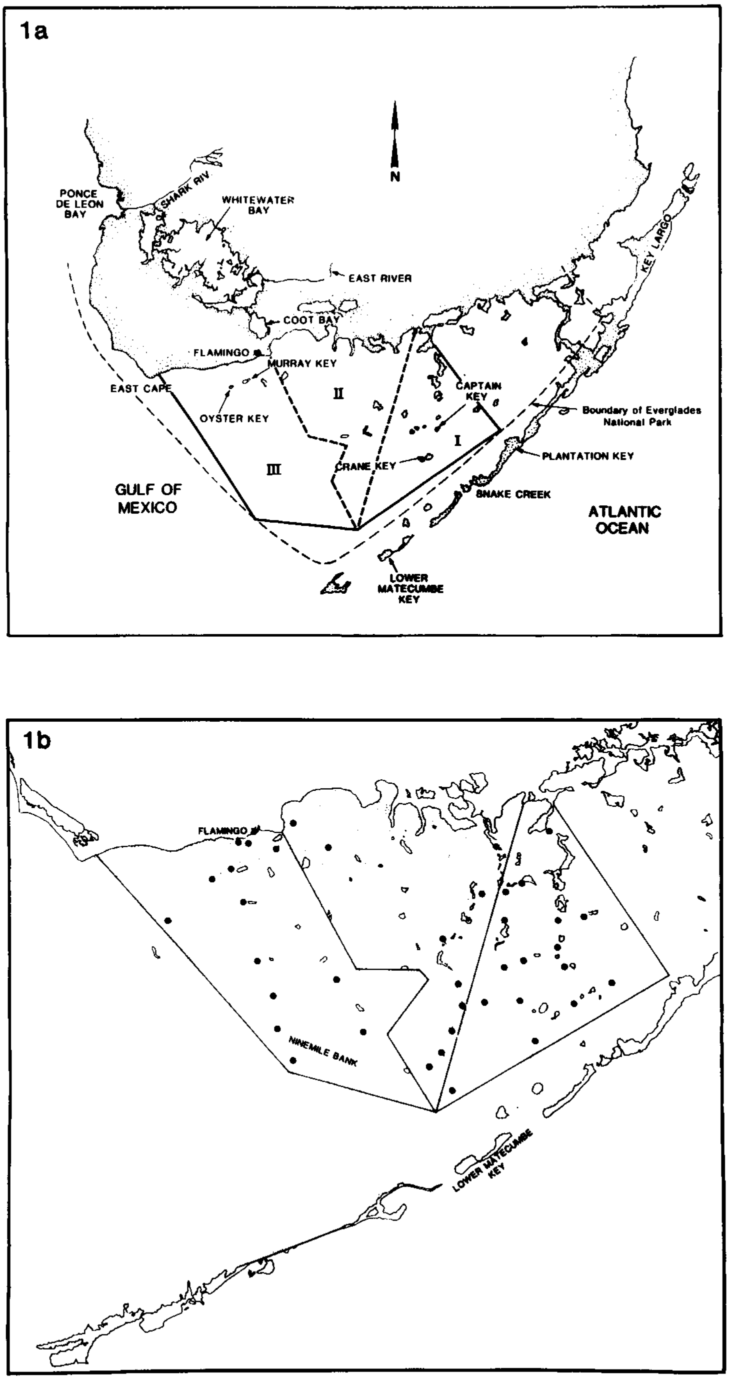

Figure 1. Diagram of the south Florida area. (a) depicts the three basin strata used in sampling fishes and environmental parameters; (b) shows the location (●) channel stations (Stratum IV) sampled in Florida Bay.

into the sediment in the vicinity of one of the seagrass samples, and the depth of penetration to bedrock recorded if ≤ 2 m. A different procedure was used in channels. All sampling for environmental characteristics in the channels took place prior to trawling. Vegetation and sediment samples were taken at the anticipated start, mid-point and end of a projected trawl line.

Plant and sediment samples were kept chilled until analyzed. Individual short shoots of each seagrass species were counted and separated from below-ground material. Shoots were rinsed in 10% phosphoric acid and then rewashed in seawater to remove carbonate, epiphytes and sediment. The plant material was dried at 80°C to a constant weight and weighed to the nearest 0.001 g. Data were averaged for each sample site for each species: *T. testudinum, S. filiforme,* and *H. wrightii.* Sediments were analyzed for organic content (loss of weight at 500°C) and silt-clay content (Thayer et al. 1987b).

Data Reduction and Analysis.—Initial analyses of spatial (stratum) and temporal (survey) trends in environmental and seagrass variables were accomplished with univariate ANOVA techniques. A product-moment correlation matrix, incorporating the data from all nine surveys, then was constructed using the following variables: mean water temperature, salinity, percent organic content of the sediment, sediment depth, water column depth, and log (X + 1) shoots$\cdot$m^{-2} of each of the three seagrass species. Principal component analysis (PCA) of this matrix produced a smaller number of composite variables, the scores of which were plotted areally to give a representation of environmental characteristics within the study area.

Analysis of the distribution of fish communities and the relationship of environmental factors to that distribution paralled the philosophy of Green and Vascotto (1978) and Field et al. (1982). First, we used cluster analysis to group stations according to similarities in juvenile fish composition. Species abundance data (numbers/hectare) from otter-trawl samples were transformed with the $\log_e$ (X + 1) function to reduce the effect of ecological dominants. The number of species then was reduced from 86 to 44 by including only those species that occurred at more than 10% of the stations of at least one survey. In addition, we excluded stations at which fewer than five species were collected. A Bray-Curtis similarity matrix then was constructed, and stations were classified with group-average sorting (Field et al. 1982). Data from all surveys were included in the analysis and therefore, any seasonal patterns would constitute added sources of variation that we did not evaluate.

The resulting station groups were analyzed by univariate and multivariate ANOVA to determine if statistically significant differences could be detected for habitat factors. The same variables used for the PCA plus the biomass (g$\cdot$m^{-2}) of each seagrass species (log transformed) were included in the analysis. After significant differences were found, we used stepwise discriminant analysis (BMDP, 1983) to search for environmental characteristics most important in distinguishing station groups. The extent to which groups were environmentally distinct was judged using discriminant functions to retrospectively assign each station to the group it most resembled environmentally. The percentage of correctly classified stations was estimated with the "jackknife" or "leave-one-out" method (Snapinn and Knoke, 1984) to reduce upward bias.

Results and Discussion

During the 9 monthly sampling visits a total of 202 stations was occupied, several on more than one occasion. A total of 35, 40, 41, and 31 different stations were sampled in Stratum I, II, III, and IV, respectively, representing 41%, 46%, 49%, and 79% of the sampleable area in each stratum. Thus, this sampling design does provide an extensive geographic basis upon which to describe habitats and fishery organisms of the study area. Summary data for the habitat characteristics are presented for each stratum in Table 1; details are presented in Thayer et al. (1987b).

Temperature and Salinity.—Water temperature was similar among strata. A typical seasonal cycle was observed with minimum values in winter and maximum values in July and September. Slightly greater differences in the average range occurred in Stratum I (12.5°C) and Stratum II (14.7°C) than elsewhere in our sampling area (10.1–11.6°C). This probably is a reflection of the shallowness and generally low water exchange that occurs in the eastern and central sections of Florida Bay (Schomer and Drew, 1982).

The largest extremes in salinity also were encountered in Strata I and II. Wide seasonal ranges in the interior region of Florida Bay are common (Schomer and Drew, 1982), and apparently are related to restricted circulation. It is possible

Table 1. Mean values for environmental and biological variables that were measured during 1984 and 1985 in Florida Bay. Data are presented as mean stratum values (see Thayer et al., 1987b for details)

Parameter	Stratum I	Stratum II	Stratum III	Stratum IV
Temperature (°C)	26.7	26.8	26.7	27.0
Salinity (‰)	36.2	36.5	35.2	36.2
Organic matter (%)	8.5	14.6	15.3	12.4
Sediment depth (m)	0.6	0.9	1.1	0.9
Water depth (m)	1.7	1.3	1.5	1.5
Thalassia shoots (No. $\cdot$ m^{-2})	514	878	594	657
Thalassia standing crop (gdw $\cdot$ m^{-2})	58.6	203.2	154.4	184.8
Halodule shoots (No. $\cdot$ m^{-2})	21	146	282	988
Holodule standing crop (gdw $\cdot$ m^{-2})	0.1	3.5	7.0	22.4
Syringodium shoots (No. $\cdot$ m^{2})	0	0	843	221
Syringodium standing crop (gdw $\cdot$ m^{2})	0	0	59.9	19.3

that water control structures along the northern portion of Everglades National Park exacerbate the normal salinity extremes in this area by manipulations of deficits and excesses of freshwater. The maximum recorded difference between station values (21‰) occurred in Stratum I. A smaller range (17‰; 28‰ in November to 45‰ in May) was found in Stratum III. Within Stratum III, near the Gulf of Mexico, the range was 16.0‰ (24‰ in September to 40.0‰ in June). The range in salinity extremes was 21‰ for the channels (Thayer et al., 1987b).

Sediment Organic Content.—The organic content of surface sediments reflects in overall hydrology and depositional characteristics of the environment and the nature of the plant community. The presence and density of seagrasses influence these parameters by modifying hydrodynamic and depositional characteristics of flowing water (Fonseca et al., 1983; Fonseca and Fisher, 1986) and because they are a source of organic matter. With the exception of the eastern stratum, average sediment organic levels generally exceeded 10% (Table 1, and Thayer et al., 1987b). There was a significant difference (ANOVA, $P < 0.001$) among strata, with the eastern stratum displaying the lowest overall level (8.5%). Strata II, III and IV were similar and significantly different from Stratum I (SNK, $P < 0.05$). A great deal of variability existed among stations and no discernible seasonal trends were apparent. Sediments having organic levels $\leq 15\%$ were present primarily in the eastern stratum between Flamingo, East Cape and the western tips of Dildo Key Bank and First National Bank, the latter of which are located to the south and southwest, respectively, of Oyster Key (Fig. 1). Comparatively high sediment organic levels ($> 15\%$) exist in the western and northwestern portion of the bay (Fig. 2a). These patterns probably are related to seagrass density and distribution. The area of $\leq 15\%$ organic carbon generally occurs in areas of relatively low standing crops of seagrasses while the region having $> 15\%$ organic carbon has relatively high above-ground seagrass biomasses (see later).

Sediment Depth.—The western Florida Bay (Stratum III) had thicker sediments than either the central area (II) or the channels (IV) sampled; both of these latter areas possessed thicker sediment veneers than Stratum I (Table 1). Stratum III generally had sediment depths > 1.0 m while the eastern portion had depths ≤ 1.0 m (Fig. 2b). This western stratum has extensive, well developed carbonate mud banks. The distribution of sediments less than and greater than 1 m thick in

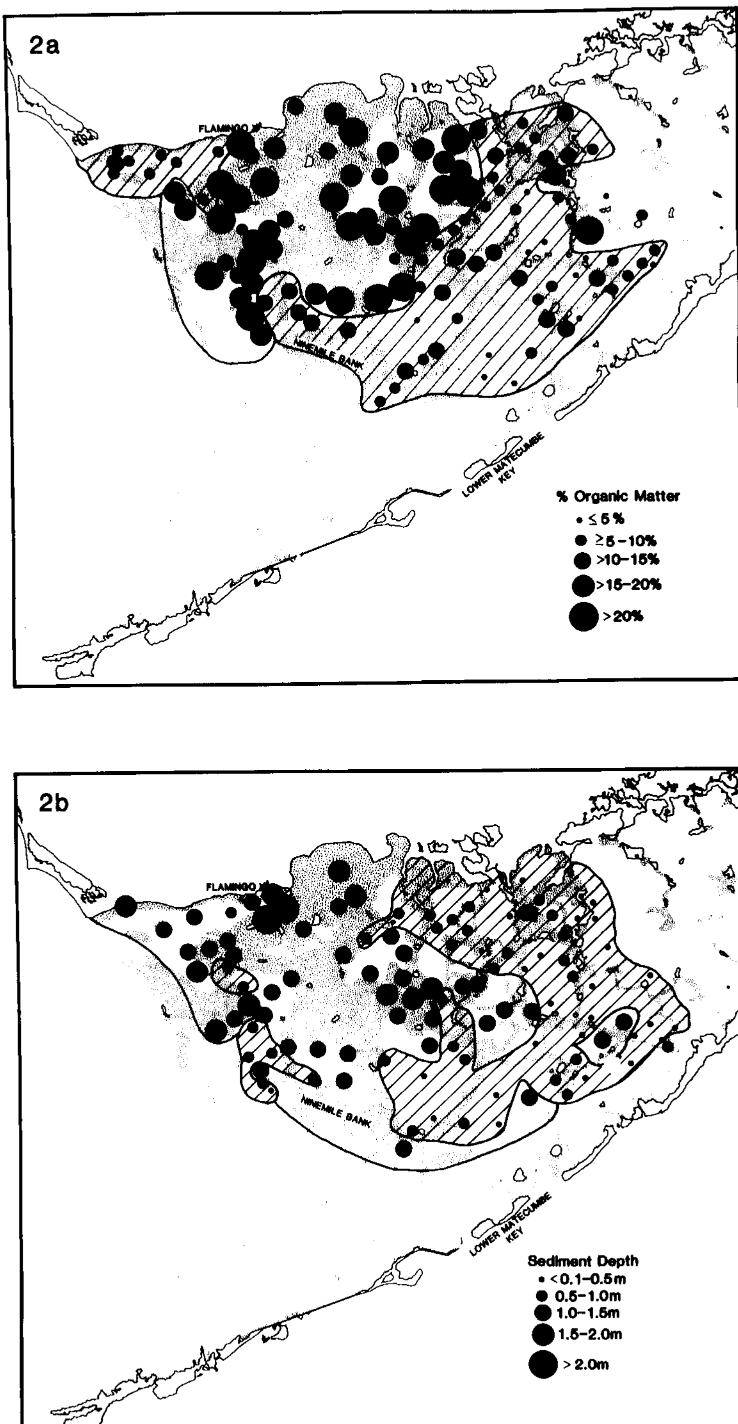

Figure 2. Diagram of the distribution in percent sediment organic matter (a) and depth of sediment at sampling stations in Florida Bay; (b) hatched areas represent organic matter levels ≤15% (a) and sediment depths ≤1 m (b).

Florida Bay generally coincided with the respective distribution of low ($\leq 15\%$) and high ($>15\%$) sediment organic levels (Fig. 2a) and low and high seagrass standing crops (see later), and generally coincide with those of Zieman and Fourqurean (1985).

Standing Crop and Shoot Density of Seagrasses.—The distribution, abundance and species composition of seagrasses differed among strata and, generally, there was high variability among stations in any single stratum. The subdivision of open water areas in Florida Bay into three strata was based on the premise that there was a general increase in the standing stock of *T. testudinum* from the northern-northeastern portion of Florida Bay to the western-southwestern section of the sample area (Zieman, pers. comm.). We had projected an average standing crop of *Thalassia* that would be lowest in Stratum I, intermediate in Stratum II, and highest in Stratum III. This premise, in fact, was not true for *Thalassia* standing crop or shoot density. This disparity may be a reflection of the stratified random sampling design we used and the fact that all seagrass samples were taken from the approximate center of each grid cell; triplicate samples taken, however, were similar and we believe give an accurate picture of plant characteristics at the stations sampled. When data for *Thalassia, Syringodium* and *Halodule* were evaluated together, however, total plant standing crop and shoot density did tend to be highest in the western portion (Table 1, Fig. 3a). Total seagrass standing crop (dry weight) averaged 221, 206 and 59 $g\ dw \cdot m^{-2}$ for Strata III, II, and I, respectively, with corresponding shoot density averages of 1,719, 1,024 and $535 \cdot m^{-2}$ (Table 1). Mean values for the channel areas (Stratum IV) were 226 $g\ dw \cdot m^{-2}$ and 1,866 $shoots \cdot m^{-2}$.

The western stratum (III) and channel areas (Stratum IV) throughout the bay displayed the greatest diversity of seagrass species. Here, *Syringodium* and *Halodule* contributed substantially to shoot densities (Fig. 3, Table 1). *Thalassia* was present at almost every site that had seagrasses (Thayer et al. 1987b). *Halodule* dominated several of the channels and was present in most. *Syringodium* was the only species we collected in Man of War Channel, and was a major component in several other channels (Fig. 3). In many of the channels sampled, *Thalassia* was present at the channel ends where water depth frequently was shallow; other species were more common toward the center.

Seagrasses (at least *Thalassia*) tend to grow most luxuriously in deeper sediments. There were significant ($P < 0.001$) relations between total standing crop or shoot number and sediment organic content $\geq 15\%$, although the correlations were not remarkable, $r = 0.5154$ and 0.4723 ($N = 105$), respectively. The overall shallowest sediment veneer and lowest organic levels generally corresponded and occurred throughout Stratum I. Here, seagrass standing crops normally were ≤ 50 $g \cdot m^{-2}$. This stratum had a significantly lower ($P < 0.001$) overall standing crop of *Thalassia* (59 $g \cdot m^{-2}$) than the other areas in Florida Bay.

Relationships among Environmental Variables.—The environmental and seagrass variables were not highly intercorrelated (Table 2). Of 36 possible product-moment correlation coefficients, only 11 were significant ($P < 0.05$), and the absolute magnitudes of these were not high. Most of the significant relationships involved sediment parameters (organic matter, silt content, depth of sediment), water depth, and the density of *Syringodium*.

Analysis of the correlation matrix by PCA identified three groups of interrelated variables: 1) organic matter-sediment depth-water depth, 2) *Halodule-Syringodium*, and 3) salinity-temperature. These three components accounted for 56% (24%, 17%, and 15% respectively) of the total variance in the original variables

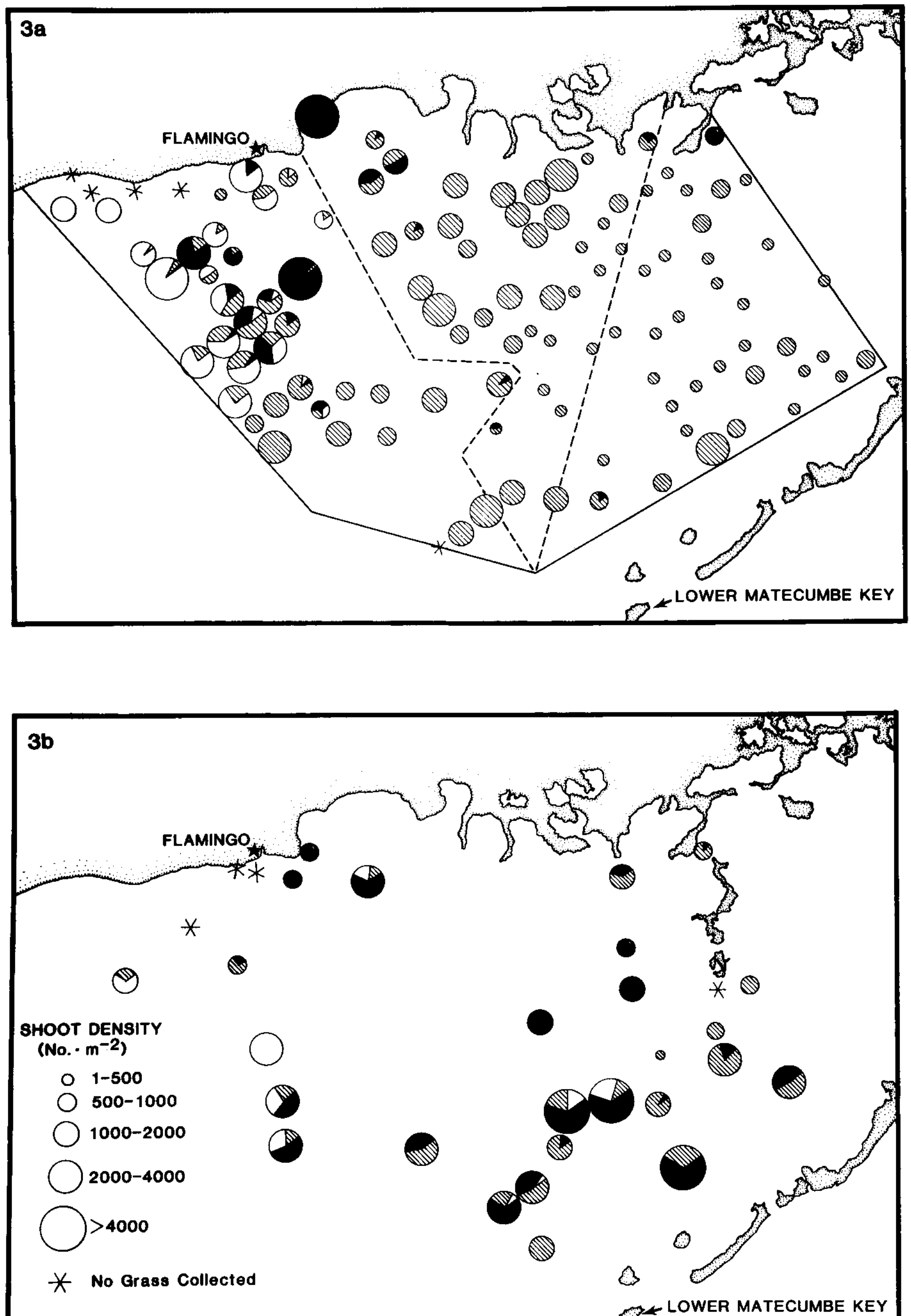

Figure 3. Distribution of seagrass shoot density in basin strata (a) and in channels (b) in Florida Bay. Hatched areas represent percentages of *Thalassia testudinum,* solid represents *Halodule wrightii,* and open represents *Syringodium filiforme.*

Table 2. Correlation matrix of environmental parameters measured in Florida Bay (OM = organic matter; SL = % silt; SD = sediment depth; D = water depth; Thal = *Thalassia*; Hal = *Halodule*; Syr = *Syringodium*). Only those coefficients significant at $P < 0.05$ are shown

	Sal	Temp	OM	SL	SD	D	Thal	Hal	Syr
Sal		0.15							
Temp									
OM				0.42	0.41	−0.30	0.18		0.26
SL					0.19	−0.23			
SD						−0.58			0.21
D									
Thal									
Hal									0.25
Syr									

(Table 3). The first two components reflect spatial trends within the study area; the third component is seasonal. Positive scores on the first component are associated with areas of high organic content, deep sediments, and relatively shallow waters; negative scores indicate low organics, thin sediments, and deeper waters. For the second component, positive scores are correlated with greater abundance of *Halodule* and *Syringodium*; negative scores corresponded to low densities or the absence of these species. Scores on the third component are positive, indicating warmer, more saline waters for May–September, and are negative during November–March, reflecting less saline and cooler waters.

Areal plots of negative and positive component scores, by station, summarize the distributional pattern of environmental (Fig. 4) and seagrass (Fig. 5) parameters over wide areas of Florida Bay. Thick, relatively organic sediments and shallower water water column depths are associated with western and north-central portions of the bay (Stratum III and the northern part of the Stratum II) and with many of the channels scattered in an arc across the western and southeastern margin (Stratum IV). A thinner, less organic sediment veneer is found in eastern and southern portions of the bay (Stratum I and the southern part of Stratum II) and along the extreme northwestern shore (Stratum II). Greatest abundances of *Halodule* and *Syringodium* are indicated in the western part of the study area (Stratum III, except along the extreme northern shore) and in many of the channels extending east to west across the southern tier of the bay (Stratum IV). Elsewhere, these species are rare.

Table 3. Prinicipal component analysis of environmental data collected in Florida Bay, 1984–1985. Seagrass densities are log (x + 1) transformed. Tabled values are correlations between raw and composite variables (varimax rotated solution)

	Composite variable		
	I	II	III
Temperature	−0.03	0.00	0.66
Salinity	−0.05	0.05	0.74
Organic matter	0.65	0.33	0.03
Sediment depth	0.84	0.16	−0.10
Water depth	−0.83	0.18	−0.09
Thalassia	0.28	−0.08	0.37
Halodule	0.05	0.72	0.18
Syringodium	0.08	0.81	−0.22
% Variation explained	23.9	16.8	15.3

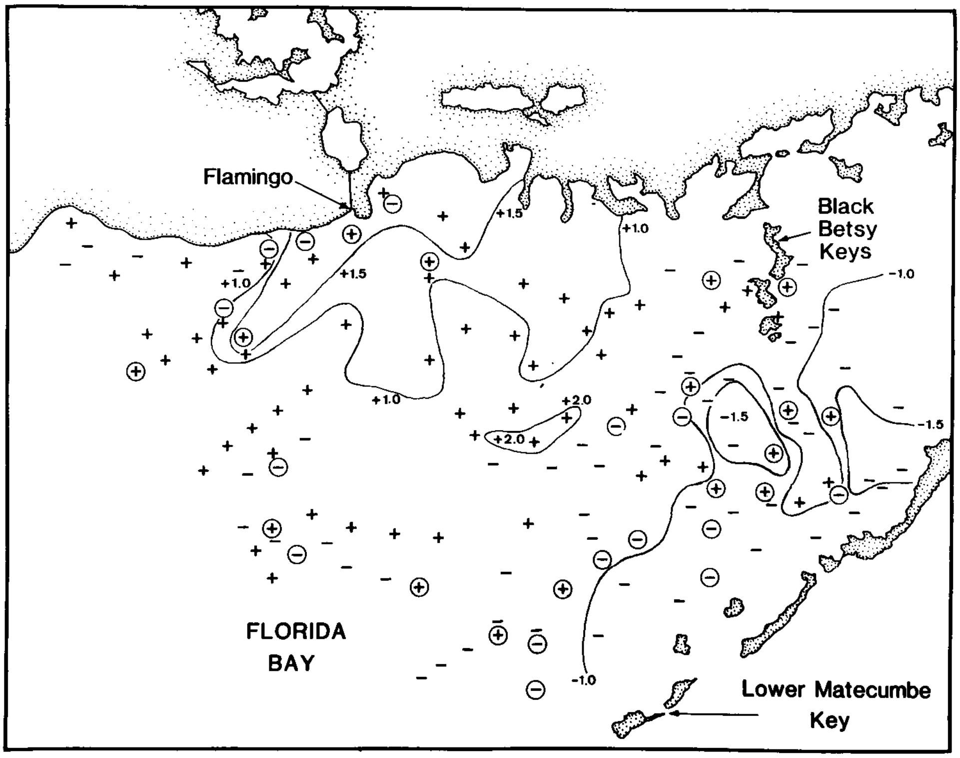

Figure 4. Distribution of positive and negative scores on Component I of a principal component analysis of environmental and seagrass parameters in Florida Bay. Positive scores imply deeper, more organic sediments and shallower water depths; negative scores imply thinner, less organic sediments and deeper water depths. Circles represent channel stations.

Further analyses of the component scores (Figs. 4, 5) indicate three major environmental subregions resembling those proposed by Zieman and Fourqurean (1985) and Zieman et al. (1989) on the basis of vegetative properties. The first subregion, encompassing western bay and channel stations, scores positively on both components. The areal extent of this region roughly corresponds to the Gulf province. The second region, encompassing the eastern portion of the study area and comprising stations with negative scores on both components, is coherent with the East Central and Atlantic subregions. The third region, characterized by stations with positive scores on the first component but negative scores on the second, resembles closely the Interior province.

Relative Abundance of Fish.—The fish community was dominated by juveniles as well as by adults of small resident forage species. A total of 35,544 fish (76% of which was taken by otter trawl) representing 93 species and 43 families was collected by both gear between May 1984 and June 1985. Only a few of the dominant species were common to both trawl gear. Eleven species contributed 90% of the total number of fish collected by otter trawl: rainwater killifish (*Lucania parva*) (31.7%); silver jenny (*Eucinostomus gula*) (27.4); pinfish (*Lagodon rhomboides*) (17.6); goldspotted killifish (*Floridichthys carpio*) (3.1); white grunt (*Haemulon plumieri*) (2.2); dusky pipefish (*Syngnathus floridae*) (2.0); pigfish (*Orthopristis chrysoptera*) (1.4); spotfin mojarra (*Eucinostomus argenteus*) (1.4); silver

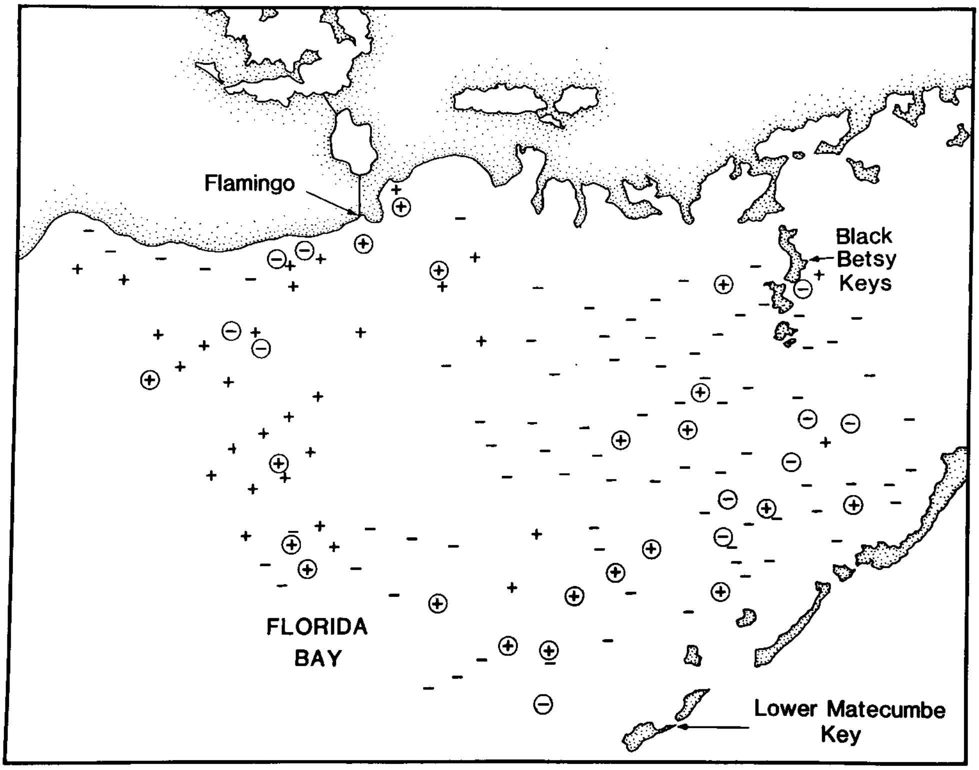

Figure 5. Distribution of positive and negative scores on Component II of a principal component analysis of environmental and seagrass parameters in Florida Bay. Positive scores imply denser stands of *Halodule wrightii* and *Syringodium filiforme;* negative scores imply lower densities or the absence of these seagrass species. Circles represent channel stations.

perch (*Bairdiella chrysoura*) (1.3); hardhead silverside (*Atherinomorus stipes*) (1.2); and gulf pipefish (*Syngnathus scovelli*) (1.1). Dominant species in the surface trawl catches included halfbeak (*Hyporhamphus unifasciatus*) (18.2%); reef silverside (*Hypoatherina harringtonensis*) (14.5); hardhead silverside (11.1); redfin needlefish (*Strongylura notata*) (8.4); hardhead halfbeak (*Chriodorus atherinoides*) (8.5); striped anchovy (*Anchoa hepsetus*) (6.3); rough silverside (*Membras martinica*) (5.6); silver jenny (2.8); rainwater killifish (2.2); and Spanish sardine (*Sardinella aurita*) (2.0). Hettler (1989) noted that many of these species are common forage organisms of piscivorous fish.

The dominant fish species in our collections were similar to those observed in other studies in south Florida. Tabb and Manning (1961) reported anchovies, mojarras and pinfish dominant in trawl collections in northern Florida Bay and Whitewater Bay. Tabb (unpubl. data), recorded a somewhat different species complement from the area of Eagle Key and Murray Key during 1964–1966, including: fringed pipefish (*Micrognathus crinigerus*), silver jenny, spotfin mojarra, pinfish, planehead filefish (*Monocanthus hispidus*), white grunt, lane snapper (*Lutjanus syngaris*) and pigfish. Schmidt (1979) found that striped and bay (*A. mitchilli*) anchovies constituted over 48% of the total trawl catch for western and southwestern Florida Bay, followed by mojarra, killifish, and pinfish. However, in our sampling, these anchovies composed less than 15% of our total catch using two gears. Weinstein and Heck (1979) reported that silver perch, pinfish, silver jenny, white grunt, pigfish, and lane snapper were the dominant species in seagrass beds near Cape Romano and Marco Island, similar to what Tabb and Manning (1962) observed for seagrass areas of Florida Bay. Carter et al. (1973) and Colby et al. (1985), working in the Ten Thousand Island area, reported a similar complement of dominant species but a preponderance of species with pelagic affinities even though several gear types were used.

Distribution of Fish among Strata.—The distribution of total numbers of organisms varied among strata. Western Florida Bay and the channels (Strata III and IV) consistently displayed a similar fish community, one that was larger in numerical abundance (13,653 and 13,520, respectively) and species composition (74 species at each stratum, both gear) than collected in other areas in Florida Bay. Of the remaining two strata, eastern Florida Bay (Stratum I) exhibited the numerically smallest demersal fish community (3,096 total individuals). Thus, the overall fish community was numerically larger in those strata (Strata III and IV) that generally exhibited the largest and most diverse seagrass assemblages (Fig. 3).

Venn diagrams were developed to depict the co-occurrence of fish species among strata for the survey as a whole. Only those species for which there were more than 10 individuals in any single stratum were included. Analysis of pooled data for the basin habitats of Florida Bay (Fig. 6) demonstrated that there were more species unique to Stratum III than to either Stratum I or II or that co-occurred among the three strata. Species captured only in the eastern-most stratum (Stratum I) included: scaled sardine (*Harengula jaguana*), Spanish sardine, great barracuda (*Sphyraena barracuda*), and clown goby (*Microgobius gulosus*). One species (hardhead silversides) was unique to the central stratum (II). Four species co-occurred between Stratum II and Stratum III: striped anchovy, gulf toadfish (*Opsanus beta*), pugnose pipefish (*Syngnathus dunckeri*), and sheepshead (*Archosargus probatocephalus*). No species were unique to the channel habitats. Twenty-two species were caught only in basins near the gulf (III) (Fig. 6). Of these 22 species, 9 species were in common with channels (Stratum IV): gray snapper (*Lutjanus griseus*), lane snapper, sailor's choice (*Haemulon parrai*), white grunt, bluestriped grunt (*Haemulon sciurus*), pigfish, grass porgy (*Calamus arctifrons*), code goby (*Gobiosoma robustum*), and scrawled cowfish.

Distribution of Fish within and between Strata.—The distribution of individuals per unit area and numbers of species per station varied within strata as well as among strata. The numerical abundance of the demersal community (otter trawl) averaged 1976 individuals$\cdot$ha^{-1} and ranged from a low 8$\cdot$ha^{-1} to 25,052$\cdot$ha^{-1}. Overall, Stratum I had the lowest mean density of fish while channel stations had the highest density (Fig. 7). In increasing order, the strata are ranked: Stratum I ($\bar{x}$ = 516 indiv$\cdot$ha^{-1}; range = 10–4,345), Stratum II ($\bar{x}$ = 1,215$\cdot$ha^{-1}; range = 8–11,909), Stratum III ($\bar{x}$ = 3,026$\cdot$ha^{-1}; range = 33–25,052), and Stratum IV ($\bar{x}$ = 3,245$\cdot$ha^{-1}; range = 18–21,526). For the basin strata of Florida Bay (Strata I–III) there was a trend for the density of fish collected to increase in a northerly direction in all but Stratum I, with maximum fish numbers at stations generally between First National Bank and Snake Bight (Fig. 7).

The distribution of numbers of species within and among strata followed a trend similar to that observed for total numbers. An average of seven species were collected on each sampling date at each station throughout the study area, and the strata were ranked as follows: Stratum I (4.7), Stratum II (5.6), Stratum III (10.5) and Stratum IV (11.6).

Because of biases associated with various collecting gear (see discussions by

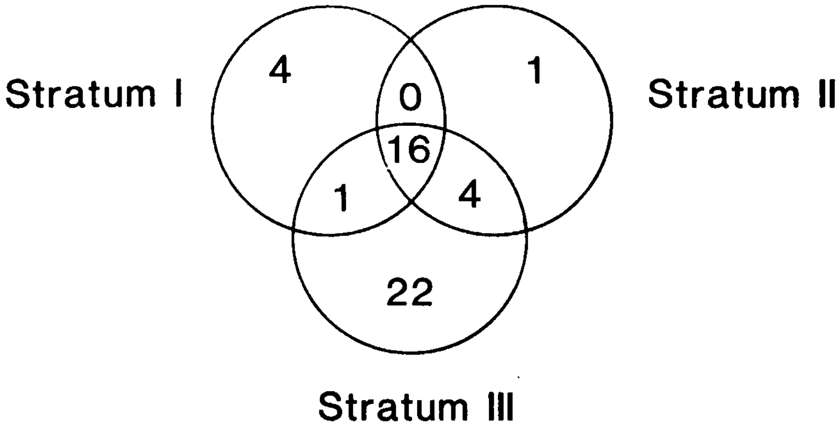

Figure 6. Diagrammatic representation of the overall similarities among numbers of fish species collected within the three basin strata in Florida Bay. Each stratum is represented by a ring in the Venn diagram and the rings intersect so that the number of species common to all strata is indicated within the intersection of all three rings; the number of species common to two of the three strata is indicated within the corresponding intersection of those two respective rings; and the number of species unique to a particular stratum in indicated outside intersections.

Kjelson and Johnson, 1978; Weinstein and Brooks, 1983; Thayer et al., 1987a) few comparisons can be made with other studies. Our estimate of fishes from bottom trawls averaged about $2 \cdot 10^3 \cdot ha^{-1}$ with a range of $8 \cdot 10^{-4}$ to $2.5 \cdot 10^4$ individuals$\cdot ha^{-1}$. Adams (1976), using drop nets, observed a standing stock average for two eelgrass beds in North Carolina of about 1.8 individuals$\cdot 10^4 \cdot ha^{-1}$ with a range of ~ 0.06–$6.0 \cdot 10^4 \cdot ha^{-1}$. Using otter trawls in the Chesapeake Bay, Weinstein and Brooks (1983) observed juvenile fish abundances regularly of less than 10^4 individuals$\cdot ha^{-1}$. Sogard (1982) observed densities of 0.2–$2.0 \cdot 10^4$ fish. ha^{-1} using a push net in Biscayne Bay seagrass beds, but, using a throw trap, Sogard et al. (1987) reported mean densities of $11 \cdot 10^4$ fish$\cdot ha^{-1}$ on several carbonate mud banks in Florida Bay. These authors also have computed values of 0.3–$1.5 \cdot 10^4 \cdot ha^{-1}$ in Apalachee Bay and $<0.5 \cdot 10^4 \cdot ha^{-1}$ in Indian River based on available literature. Individual stations in the study area provided values that equalled or exceeded (e.g., Fig. 6) many published abundance and biomass values. For the most part, the stations falling into this category were located in Stratum III and Stratum IV, and have generally dense stands of mixed seagrass (Fig. 3).

Interactions among Environmental Variables and Fishes.—Two major station groups, representing two distinct fish community types, emerged from cluster analyses of otter trawl data (Fig. 8); 88% of the stations fell into these two clusters. Cluster 1, which included 58 of the 139 stations in the analysis, occurred in shallow water areas of eastern and central Florida Bay (Stratum I and the southern part of Stratum II) and in the easternmost channels (Stratum IV). The juvenile fish community at these stations was relatively sparse in abundance, biomass, and number of species present (Table 4). Only silver jenny and pinfish averaged $>100 \cdot ha^{-1}$. Species occurring at half or more of the stations were silver jenny, pinfish, goldspotted killifish, rainwater killifish, and dusky pipefish.

Cluster 2, which included 64 stations, was distributed over the shallow water areas of western and northern Florida Bay (Stratum III and the northern part of Stratum II) and in over half of the channels (Stratum IV). These stations were relatively rich in fish abundance, biomass, and numbers of species. Species with

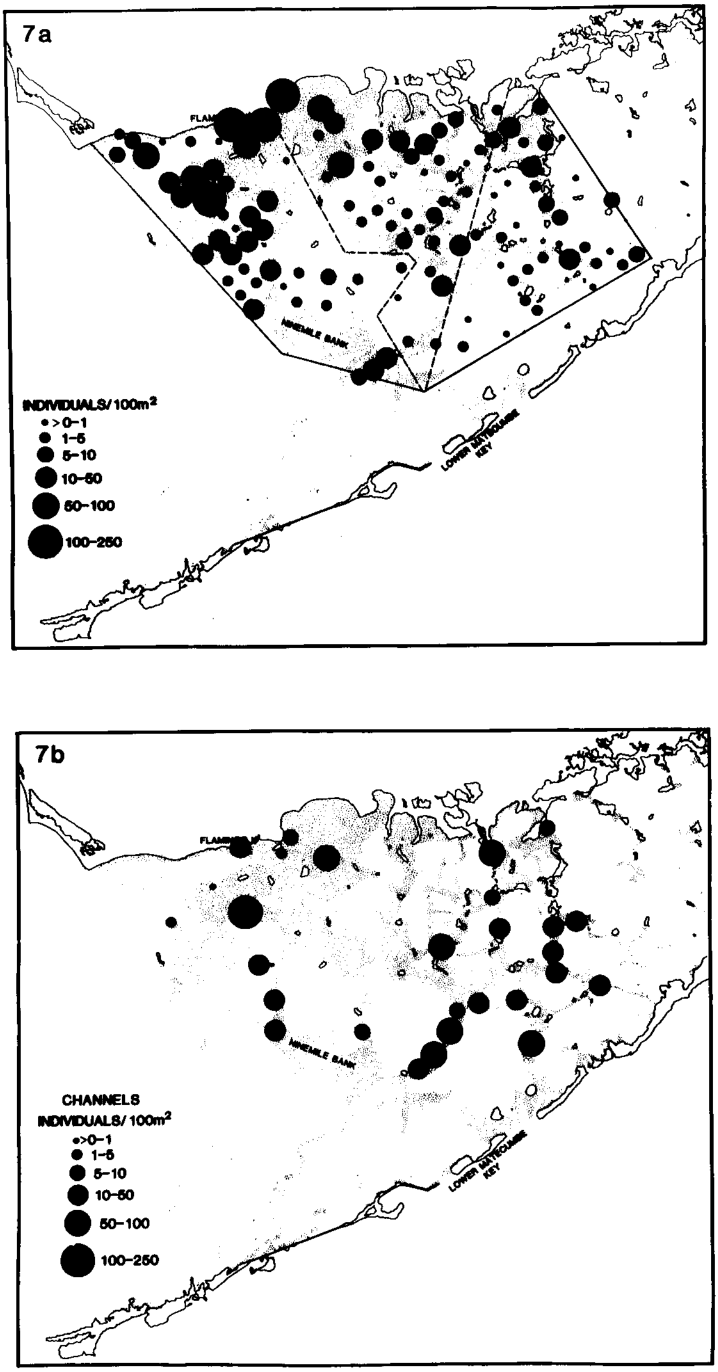

Figure 7. Diagrammatic representation of the distribution of fish (no·m^{-2}) at basin stations (a) and in channels (b) sampled in Florida Bay.

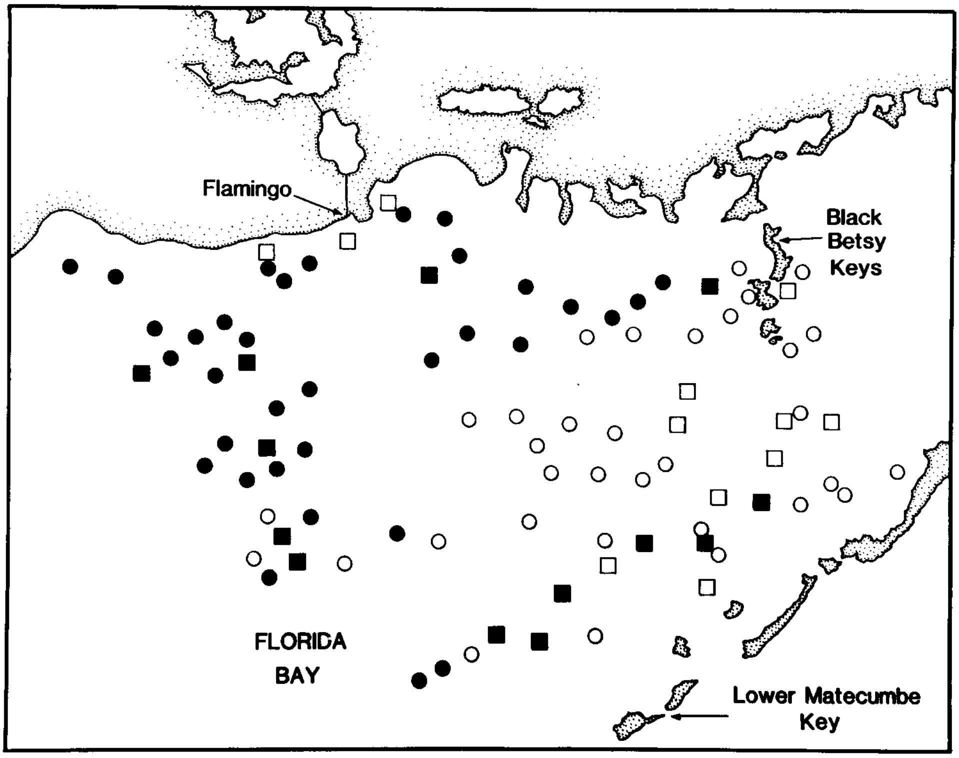

Figure 8. Distribution of stations clustered according to the community composition of fishes in Florida Bay. Open symbols are Cluster I stations; closed symbols are Cluster II stations. Circles represent open water stations (Strata I–III); squares are channel stations (Stratum IV).

abundances $>100 \cdot ha^{-1}$ were rainwater killifish, pinfish, silver jenny, goldspotted killifish, and white grunt, and those occurring at half or more of the stations included rainwater killifish, pinfish, silver jenny, dusky pipefish, gulf toadfish, goldspotted killifish, gulf pipefish, white grunt, and dwarf seahorse. Several species of recreational importance in the southeast were more prevalent in this cluster: sheepshead, spotted seatrout, white grunt, gray snapper and pigfish (Table 4).

The two station groups defined by cluster analysis were considered separate populations for purposes of statistical comparison. Besides obvious differences in fish populations, these groups varied significantly in the characteristics of their sediments and the kinds and quantities of their seagrass populations (ANOVA, MANOVA $P < 0.05$) (Table 5). Stations assigned to Cluster 1 (sparse fish populations) had thinner, less organic sediments and smaller populations of *Halodule* and *Syringodium* than did stations of Cluster 2 (more abundant fish populations). Stations in Cluster 1 tended to consist of monotypic stands of *Thalassia* with standing crops $<250 \text{ g} \cdot m^{-2}$ and shoot densities $\leq 2{,}000 \cdot m^{-2}$, while Cluster 2 tended to consist of stations with a mixed plant community with standing crops in excess of $250 \text{ g} \cdot m^{-2}$ and shoot densities $>2{,}000 \cdot m^{-2}$ (Fig. 3, and Thayer et al., 1987b). Stepwise discriminant analysis identified organic content of the sediment, water column depth, and the numerical abundance of *Halodule* and *Syringodium* as variables most important in differentiating the two station groups (Table 5). Negative scores on this function were associated with Cluster 1 stations (mean

Table 4. Fish communities associated with two major clusters of stations in Florida Bay based on otter trawl samples. Values are mean number of individuals per N stations. Parenthetical values are the number of stations at which a given species was captured. Species listed are those occurring at 10 or more stations in either of the two station groups

Scientific name	Common name	N = 58 Cluster 1	N = 64 Cluster 2
Archosargus probatocephalus	Sheepshead	1 (1)	32 (25)
Bairdiella chrysoura	Silver perch	4 (5)	80 (30)
Calamus arctifrons	Grass porgy	—	8 (10)
Callionymus pauciradiatus	Spotted dragonet	3 (10)	2 (8)
Chilomycterus schoepfi	Striped burrfish	2 (6)	4 (12)
Cynoscion nebulosus	Spotted seatrout	1 (6)	7 (18)
Eucinostomus argenteus	Spotfin mojarra	58 (20)	30 (9)
Eucinostomus gula	Silver jenny	490 (58)	851 (56)
Floridicthys carpio	Goldspotted killifish	66 (39)	151 (37)
Gobiosoma robustum	Code goby	3 (10)	13 (22)
Haemulon plumieri	White grunt	11 (9)	143 (36)
Hippocampus zosterae	Dwarf seahorse	34 (26)	40 (36)
Lactophrys quadricornis	Scrawed cowfish	1 (3)	5 (12)
Lagodon rhomboides	Pinfish	129 (43)	994 (58)
Lucania parva	Rainwater killifish	68 (39)	2,028 (60)
Lutjanus griseus	Gray snapper	7 (10)	15 (29)
Lutjanus synagris	Lane snapper	1 (5)	24 (10)
Opsanus beta	Gulf toadfish	15 (23)	57 (49)
Orthopristis chrysoptera	Pigfish	6 (8)	80 (26)
Sphoeroides nephelus	Southern puffer	2 (6)	4 (12)
*Syngnathus dunckeri**	Pugnose pipefish	4 (10)	14 (25)
Syngnathus floridae	Dusky pipefish	20 (33)	90 (56)
Syngnathus scovelli	Gulf pipefish	12 (24)	56 (37)
Synodus foetens	Inshore lizardfish	5 (13)	5 (14)
Mean richness (species/station)		8.8	12.8
Mean number (fish/hectare-station)		1,169	4,845
Mean biomass (kg/hectare-station)		6.27	16.53

* This species may have been misidentified and may be *Anarchopterus criniger* (=*Micrognathus criniger*).

score = −0.73) and denoted less organic sediments, slightly deeper waters, and lower abundances of *Halodule* and *Syringodium*. Positive scores associated with Cluster 2 stations (mean = +0.66), implied the opposite conditions.

The ability of the identified variables to separate the two station groups (themselves defined on the basis of fish composition) was evaluated by assigning each station to a group solely on the basis of its score on the discriminant function. In 79% of cases, stations were correctly assigned to groups. We conclude, therefore, that juvenile fish distributions in Florida Bay are influenced by the distribution of seagrass characteristics and sediment types in the bay, with richer and more diverse fish communities found where sediments are more organic and seagrass populations more diverse. Analysis of the distribution of spotted seatrout and gray snapper indicated that high densities of *Syringodium* and *Halodule* are particularly diagnostic of seatrout and gray snapper habitat, respectively (ms in prep.; Thayer et al., 1987b). The low densities of fishes in the interior of our sampling area and the generally restricted circulation for this area (Schomer and Drew, 1982) also suggest that hydrographic patterns may play an important role in fish distribution within the bay.

Without experimental evidence in the regions bounded by these two clusters, we can only conjecture that the diversity of plant species, their density and sediment organic or detrital levels are influential in regulating fish abundance and the complement of species utilizing habitats in Florida Bay. The habitat com-

Table 5. A. Means and significance levels (ANOVA and MANOVA) for variables used to distinguish Cluster 1 stations from Cluster 2 stations. Significance levels (denoted by * at $P < 0.05$) are for $\log_{10}$ $(X + 1)$ transformations of seagrass data; B. Variables included in the discriminant function, standardized discriminant coefficients, and correlation coefficients relating variables to the function; C. Numbers of stations assigned to each cluster by classification analysis

A. Variable	Cluster 1	Cluster 2	Significance
Temperature (°C)	27.4	27.2	0.75
Salinity (‰)	36.1	35.9	0.80
Organic matter (%)	12.6	16.4	0.00*
Sediment thickness (m)	0.9	1.1	0.05*
Water depth (m)	1.5	1.3	0.22
Thalassia (shoots·m²)	685	813	0.54
(g dwt·m²)	131	248	0.15
Halodule (shoots·m²)	327	752	0.00*
(g dwt·m²)	7	18	0.00*
Syringodium (shoots/m²)	61	721	0.00*
(g dwt/m²)	5	50	0.00*
MANOVA: Wilk's Lambda = 0.67, Equivalent F = 14.82			0.00*

B. Discriminant function	Standardized coefficient	Correlation coefficient
Organic matter	0.45	0.50
Water depth	−0.35	−0.16
Halodule density	0.50	0.44
Syringodium density	0.74	0.67

		Predicted group membership	
C. Actual group	N	Cluster 1	Cluster 2
Cluster 1	57	46 (81%)	11 (19%)
Cluster 2	63	14 (22%)	49 (78%)

plexity may be a function of total plant biomass or surface area (Heck and Orth, 1980; Stoner, 1980); whether the meadow is generally in a high current or low current area (Thayer et al. 1984; Fonseca and Fisher, 1986); or seagrass species composition (Stoner 1982; 1983; Virnstein and Howard, 1987). This latter may be due to species composition per se, biomass or blade density. Virnstein and Howard (1987) have shown that food resource density (epifauna and gastropods) was greater on *Halodule* while crustacean resource density was greatest on *Thalassia* on an areal basis. However, when data were evaluated in terms of plant surface area, crustaceans were most abundant on *Syringodium.* Stoner (1982) noted that fish foraging efficiency for crustaceans was lower in *Syringodium* meadows than in *Halodule* meadows. Stoner (1984) also has noted that pinfish tend to be more prevalent in *Halodule* beds than in either *Syringodium* or *Thalassia.* Our data also suggest that sediment organic content, which is a reflection of seagrass litter deposition and hydrographic patterns, is an important component in discriminating abundance and composition of fishes in Florida Bay. Sogard et al. (1987) and Powell et al. (1986) also found positive relations between some species of fish utilizing carbonate mud banks in Florida Bay and seagrass litter. Thus, food resources, foraging efficiency, and possibly fish species composition apparently are affected by seagrass species composition and probably by such factors as plant blade width, height and density. Experimental evidence on factors regulating habitat use or value are limited and require considerably more effort.

Both channel and non-channel areas adjacent to banks present relief which adds to the complexity of the habitat and may be important in resource and refuge availability. Additionally, the stations in the western portion of Florida Bay, at which there were comparatively high densities and diversities of fishes, also are in the vicinity of the major water exchange between East Cape and First National Bank. This appears to be a major entrance area into the western bay for larval fishes spawned in the Gulf of Mexico (Powell et al., 1987; this Symposium). Additionally, tidal currents are stronger here than in other areas having smaller tidal ranges (Sogard, pers. comm.). However, the presence of extensive banks in the vicinity probably reduces the scouring effects of tidal currents, providing a relatively quiescent environment on the leeside on which larvae can settle out of the plankton. The bank habitats near the gulf have an intermediate abundance and the highest diversity of fishes of the bank habitats sampled in Florida Bay (Powell et al., 1986; Sogard et al., 1987), and may serve as one source of juveniles to nearby basins. The varied seagrass habitat in western Florida Bay adjacent to these banks would provide a wide diversity for refuge and sources of food for resident fishes as well as transient species of commercial and recreational value. The overall low densities of fish in the interior of our sample area, principally the interior of Strata I and II, may be a function of limited larval dispersal and juvenile recruitment resulting from reduced water circulation within this area and between adjacent areas. We believe that one fruitful area of research on fish communities in the bay deals with circulation within the bay and dispersal of fishes within the bay, directed in particular at addressing the low densities of fauna in the interior of the bay. A second area that should be addressed is the utilization of *Halodule, Syringodium* and mixed seagrass by juvenile fishes recruiting to the bay and by resident species.

Acknowledgments

This research was part of a larger study supported through a contract from Everglades National Park to the Beaufort Laboratory of the Southeast Fisheries Center of NMFS. A number of individuals, both from NMFS and NPS, were critical to the success of this phase of the study. Particular thanks are extended to W. Hettler and M. LaCroix who participated in almost every phase and most of the collecting trips. D. Colby, D. Peters, P. Marraro, Lt. J. Rivera, J. Kenworthy, A. Powell, D. Hoss, K. Rittmaster and V. Thayer from Beaufort, all participated in sampling, design modifications, and/or sample processing. G. Hendrix, J. Tilmant, M. Robblee, E. Rutherford and P. Harrigan of Everglades National Park provided invaluable advice or physical assistance. We also benefited from discussions with G. Powell and S. Sogard from Audubon Society and J. Zieman and J. Fourqurean from the University of Virginia. Comments from two referees added measurably to the manuscript. We are indebted to J. Fulford for typing this manuscript and to H. Gordy for drawing the figures.

Literature Cited

Adams, S. M. 1976. The ecology of seagrass, *Zostera marina* (L.), fish communities. I. Structural analysis. J. Exp. Mar. Biol. Ecol. 22: 269–291.

BMDP Statistical Software. 1983. University of California Press, Berkeley 733 pp.

Carter, M. R., L. A. Burns, T. R. Cavinder, K. R. Duggen, P. C. Fore, D. B. Hicks, H. L. Revelles and T. W. Schmidt. 1973. Ecosystem analysis of the Big Cypress Swamp and estuaries. U.S. Environmental Protection Agency, Atlanta, Georgia. 450 pp.

Colby, D. R., G. W. Thayer, W. F. Hettler and D. S. Peters. 1985. A comparison of forage fish communities in relation to habitat parameters in Faka Union Bay, Florida and eight collateral bays during the wet season. NOAA Tech. Memo. NMFS-SEFC-162. 87 pp.

Davis, G. E. 1982. Fishery management conflicts in Everglades National Park. Mar. Rec. Fish. 7: 65–75.

Field, J. G., K. R. Clarke and R. M. Warwick. 1982. A practical strategy for analyzing multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8: 37–52.

Fonseca, M. S. and J. S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. Mar. Ecol. Prog. Ser. 29: 15–22.

———, J. C. Zieman, G. W. Thayer and J. S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. Est. Coast. Shelf Sci. 17: 367–380.

Green, R. H. and G. L. Vascotto. 1978. A method for the analysis of environmental factors controlling patterns of species composition in aquatic communities. Water Res. 12: 583–590.

Heck, K. L., Jr. and R. J. Orth. 1980. Structural components of eelgrass (*Zostera marina*) meadows in the lower Chesapeake Bay—decapod crustacea. Estuaries 3: 289–295.

Hettler, W. F., Jr. 1989. Food habits of juveniles of spotted seatrout and gray snapper in western Florida Bay. Bull. Mar. Sci. 44: 155–162.

Kjelson, M. A. and G. N. Johnson. 1978. Catch efficiencies of a 6.1-meter otter trawl for estuarine fish populations. Trans. Am. Fish Soc. 107: 246–254.

Lindall, W. N., Jr. and C. H. Saloman. 1977. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Mar. Fish. Rev. 1262: 1–7.

Massman, W. H., E. C. Ladd and H. N. McCurcheon. 1952. A surface trawl for sampling young fishes in tidal river. Trans. 17th N. Am. Wildl. 386–392.

Odum, W. E., C. C. McIvor and T. J. Smith, III. 1982. The ecology of the mangroves of south Florida: a community profile. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS-81/24. 144 pp.

Powell, A. B., D. E. Hoss, W. F. Hettler, D. S. Peters, L. Simoneaux and S. Wagner. 1987. Abundance and distribution of ichthyoplankton in Florida Bay and adjacent waters. South Florida Res. Cent. Report SFRC-87/01. 45 pp.

Powell, G. V. N., S. M. Sogard and J. G. Holmquist. 1986. Ecology of shallow water bank habitats in Florida Bay. Final Report to Everglades National Park, Contract No. CX5280-3-2339. 259 pp.

Schomer, N. S. and R. D. Drew. 1982. An ecological characterization of the lower Everglades, Florida Bay and the Florida Keys. U.S. Fish Wildl. Serv. Biol. Serv., Prog. FWS/OBS-82/58.1. 246 pp.

Schmidt, T. W. 1979. Ecological study of fishes and the water quality characteristics of Florida Bay, Everglades National Park, Florida. Everglades National Park, Final Project Report No. RSP-EVER-N-36. 145 pp.

Snapinn, S. M. and J. D. Knoke. 1984. Classification error rate estimators evaluated by unconditional mean square error. Technometrics 26: 371–378.

Sogard, S. M. 1982. Feeding ecology, population structure, and community relationships of a grassbed fish, *Callionymus pauciadiatus,* in southern Florida. M. S. Thesis, U. Miami, Coral Gables. 103 pp.

———, G. V. N. Powell and J. G. Holmquist. 1987. Epibenthic fish communities on Florida Bay banks: relationships with seagrass cover and physical environment. Mar. Ecol. Prog. Ser. 40: 25–39.

Stoner, A. W. 1980. The role of seagrass biomass in the organization of benthic macrofaunal assemblages. Bull. Mar. Sci. 30: 537–551.

———. 1982. The influence of benthic macrophytes on the foraging behavior of pinfish, *Lagodon rhomboides* (Linnaeus). J. Exp. Mar. Biol. Ecol. 58: 271–284.

———. 1983. Distribution ecology of amphipods and tanaidaceans associated with three seagrass species. J. Crust. Biol. 3: 505–518.

———. 1984. Distribution of fishes in seagrass meadows: role of macrophyte biomass and species composition. Fish. Bull. 81: 837–846.

Tabb, D. C. and D. L. Dubrow. 1962. The ecology of northern Florida Bay and adjacent estuaries: part I—aspects of the hydrology of northern Florida Bay and adjacent estuaries. Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 39: 6–38.

——— and R. B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. Bull. Mar. Sci. Gulf Carib. 11: 552–649.

——— and ———. 1962. The ecology of northern Florida Bay and adjacent estuaries: part II—aspects of the biology of northern Florida Bay and adjacent estuaries. Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 39: 39–79.

Thayer, G. W., D. R. Colby and W. F. Hettler, Jr. 1987a. Utilization of the red mangrove prop root habitat by fishes in south Florida. Mar. Ecol. Prog. Ser. 35: 25–38.

———, W. J. Kenworthy and M. S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: a community profile. U.S. Fish and Wildl. Serv. FWS/OBS-84/02. 147 pp.

———, W. F. Hettler, Jr., A. J. Chester, D. R. Colby and P. J. McElhaney. 1987b. Distribution and abundance of fish communities among selected estuarine and marine habitats in Everglades National Park. South Florida Research Center, Rept. SFRC-87/02. 166 pp.

Virnstein, R. W. and R. K. Howard. 1987. The mobile epifauna of marine macrophytes in the Indian River lagoon, Florida. I. Comparisons among three species of seagrasses from adjacent beds. Bull. Mar. Sci. 41: 1–12.

Weinstein, M. P. and H. A. Brooks. 1983. Comparative ecology of nekton residing in a tidal creek and adjacent seagrass meadow: community composition and structure. Mar. Ecol. Prog. Ser. 12: 15–27.

——— and K. L. Heck, Jr. 1979. Ichthyofauna of seagrass meadows along the Caribbean coast of

Panama and in the Gulf of Mexico: composition, structure and community ecology. Mar. Biol. 50: 97–104.

Zieman, J. C. 1982. The ecology of the seagrasses of south Florida: a community profile. U.S. Fish. Wildl. Serv. Biol. Serv. Prog. FWS/OBS-82/25. 124. 26 pp.

——— and J. W. Fourqurean. 1985. The distribution and abundance of benthic vegetation in Florida Bay, Everglades National Park. Final Report to South Florida Research Center, Everglades National Park. 63 pp. + 42.

———, ——— and R. L. Iverson. 1989. Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. Bull. Mar. Sci. 44: 292–311.

DATE ACCEPTED: December 11, 1987.

ADDRESS: *U.S. Department of Commerce, National Marine Fisheries Service, NOAA, Southeast Fisheries Center, Beaufort Laboratory, Beaufort, North Carolina 28516-9722.*